Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

84C

Circular No. 719

March 1945 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Explosibility and Fire Hazard of Ammonium Nitrate Fertilizer

By R. O. E. Davis, *principal chemist, Division of Soil and Fertilizer Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

CONTENTS

	Page
Summary	1
Explosion hazard	1
Fire hazard	2
Uses of ammonium nitrate	2
Industrial explosions	3
Decomposition reactions	4
Explosion hazard	5
Effects of heating	5
Sensitivity to large fires	7
Detonation	7
Propagation of explosion	8
Impact and friction tests	9
Effects of added inorganic substances	10
Addition of organic materials and oxidizable powders	13
Fire hazard	14
Combustion of ammonium nitrate alone	14
Influence of added materials	15
Spontaneous combustion due to ammonium nitrate	16
Flash point of ammonium nitrate	17
Bags and other containers	17
Secondary hazard of ammonium-nitrate fire	21
Safety measures	21
Literature cited	22

SUMMARY

EXPLOSION HAZARD

Ammonium nitrate is employed both as a nitrogen fertilizer and as a high explosive, but a high-velocity detonator in sufficient quantity is required to energize the mass of the material.

Under favorable conditions of pressure, rapid heating, and retention of heat, ammonium nitrate may be exploded partially from heat alone near 300° C., but Munroe failed to find any instance of explosion of the salt in ordinary containers or in bulk when involved in large conflagrations of buildings or cargo vessels.

Explosion by impact or friction is very difficult and requires favorable conditions obtained by design. Sensitivity is decreased by the presence of alkalies and alkaline earths and is increased by the presence of acid, as nitric acid formed in decomposition of ammonium nitrate at a moderately low temperature.

Ammonium nitrate-ammonium sulfate mixture in 50–50 proportion gave negative results in falling-weight, friction, and detonation tests, as was true also of mixtures with other ammonium salts and with superphosphate.

Explosibility is decreased by the presence of inert, nonoxidizable materials. An explosion tends not to be propagated throughout the mass unless energized from without. Thermal decomposition,

beginning below 100° C., is endothermic, and not until the temperature of the decomposing salt reaches about 260° to 350° does the reaction become sufficiently exothermic to produce heat in excess of that absorbed by adjacent quantities of decomposing salt. Below this the explosive wave is not propagated.

Large grains or spherical granules tend to decrease the explosibility of ammonium nitrate as well as of other explosives.

Ammonium nitrate is not considered explosive under transportation conditions or when stored in wooden receptacles or paper bags by itself and apart from other explosive substances.

Fire Hazard

Ammonium nitrate in bulk offers much the same fire hazard as sodium nitrate; that is, mostly an indirect hazard from the liberation of oxygen at moderately high temperatures, which tends to increase the intensity and spread of a fire.

Readily oxidizable metallic powders in contact with wet ammonium nitrate may result in spontaneous combustion. Zinc powder seems to be most reactive under such conditions.

The presence of 5-percent aluminum, iron, or zinc powder with dry material does not appreciably increase its inflammability. Experiments with 5-percent charcoal produced no burning by direct contact with a flame, but with 11-percent charcoal it burned with very small flame. With 5-percent wood powder decomposition occurred without flame.

With the addition of paraffin up to 30 percent, heating on a steel plate caused fuming and decomposition and in one test at 300° C. a small flame.

Bags impregnated with nitrate-sulfate, 40–60, are more combustible than ordinary burlap bags. Strips of paper and burlap impregnated with ammonium nitrate and sodium nitrate are more combustible than untreated fabric, but both nitrates increase combustibility to about the same extent.

Organic or other easily oxidizable substances impregnated or in contact with ammonium nitrate produce violent combustion on ignition.

Copper is the only common metal that reacts appreciably with molten ammonium nitrate, producing nitrite, which is less stable than nitrate, and increasing the tendency to violent conflagration or explosion.

Decomposition of ammonium nitrate at temperatures below 100° C. into ammonia and nitric acid produces a greater fire hazard under some conditions in mixtures than is found in sodium nitrate.

Mixtures containing superphosphate, ammonium nitrate, and organic meal may give rise to spontaneous combustion from oxidizing reactions that sometimes begin at ordinary room temperatures. Ignition takes place when the temperature reaches 90° to 95° C. Neutralization with ammonia removes this hazard.

USES OF AMMONIUM NITRATE

Nitrogen is a constituent of most explosives, an essential fertilizer for plant growth, and an element required for the nutrition of man and animals. Ammonium nitrate, 35-percent nitrogen, is an important explosive and also an excellent nitrogen fertilizer. It has been used for many years for both purposes. In the explosives industry it is usually employed either as the pure compound or in combination with TNT or other explosive materials. The fertilizer industry has used ammonium nitrate mixed with limestone to make Cal-Nitro or similar mixtures and in ammonia-water solution as Nitrogen Solution.

During the 1943–44 fertilizer season, as a result of conversions by war plants, large quantities of ammonium nitrate (93 to 95 percent pure) were made available for the manufacture of fertilizers and as a nitrogen fertilizer for direct use on farms. In such use the question is frequently raised as to the explosion and fire hazards involved. It is the purpose of this circular to review the evidence bearing on the subject and to make recommendations for handling ammonium nitrate in fertilizer factories and on farms.

INDUSTRIAL EXPLOSIONS

Until a disastrous explosion occurred at Oppau, Germany, in 1921, it was commonly considered that ammonium nitrate offered no explosion hazard under the usual conditions of handling and use as a fertilizer. Previous to that disaster, a number of accidents of lesser violence involving ammonium nitrate occurred in Germany. Some of the more important of these are cited here. In 1906, at Witten, a violent explosion involved ammonium nitrate, but this could not be definitely considered the cause, since both TNT and potassium nitrate were present. On July 30, 1916, at Würgendorf, about 400 tons of Donarit, an explosive of 80 percent ammonium nitrate, 12 percent TNT, and 4 percent each of nitroglycerin and grain meal, stored in steel drums, was the center of a great explosion. The explanation attributed to this was that absorption of heat from the sun by the metal drums had raised the temperature, starting decomposition of the confined material and culminating in an explosion.

Three other outstanding explosions in Germany followed blasting of caked materials containing ammonium nitrate: Ammonium nitrate fertilizer surplus from a munition plant in two railroad cars at Stolberg, on April 12, 1920; ammonium nitrate alone in a car at Kriewald, on July 26, 1921; and the great mass storage of 5,000 short tons of ammonium sulfate-ammonium nitrate at Oppau, on September 21, 1921 (*4*).[1]

In the Oppau explosion not only was mass action involved but, because of the great quantity of enclosing caked material, certain factors were probably supplied in the interior of the mass favorable to transmission of the detonation throughout the whole quantity; for instance, the formation of nitric acid by decomposition near 100° C. It was estimated that 586 persons were killed or missing and 1,952 injured; 2,138 buildings were completely destroyed and 1,450 damaged.

In the United States also, a number of accidents during or near the World War I period involved ammonium nitrate. On April 14, 1920, a fire occurred on the steamer *Hallfried*, in dock at Brooklyn, N. Y., discharging a cargo of raw skins, paper, ammonium nitrate, nitrate of soda, some chlorate, and other materials (*7*). To the chlorate was attributed the start of the fire, but involved also were 8,460 casks of the cargo containing 4,230,000 pounds of ammonium nitrate stored in 3 compartments. In 2 of the compartments or already removed to the adjacent lighters all casks, containing 1,944,500 pounds of ammonium nitrate, were destroyed, but those (2,077) in the third compartment were unloaded after the fire, mostly in sound condition. There was no explosion, despite the fierceness of the fire. Explosions occurred at the Oakdale, N. J., plant of the Aetna Powder Co. on September 15, 1916; at the du Pont plant, Gibbstown, N. J., on January 14, 1916; and at the T. A. Gillespie Loading Co. plant, at Morgan, N. J., on October 4, 1918; all three explosions occurred during the manufacture of ammonium nitrate, apparently starting in crystallizing pans.

---

[1] Italic numbers in parentheses refer to Literature Cited, p. 22.

A number of papers relating to the explosibility and fire hazards of ammonium nitrate have been published. Charles E. Munroe, explosives chemist, of the United States Bureau of Mines, acting as chairman of the Committee on the Investigation of the Explosibility of Ammonium Compounds, National Research Council, reviewed earlier literature and current information and conducted a number of experiments (*7*), a summary of which was published in 1922. The Chemisch-Technischen Reichsanstalt in Germany began an investigation that culminated in the publication (1925–27) of a series of articles by Herman Kast (*4*, *5*) on the explosibility of ammonium salts. A brief summary follows of some of the salient facts concerning the explosion and fire hazards of ammonium nitrate, based primarily upon published material.

DECOMPOSITION REACTIONS

Over a period of 15 years, Berthelot (*1*), the famous French chemist, investigated the thermal decomposition of ammonium nitrate and concluded that seven equations represented the different reactions obtainable by heating it. These reactions and the equations representing them are as follows:

1. The dissociation of solid or molten ammonium nitrate into nitric acid and ammonia as gases: $NH_4NO_3 = HNO_3 + NH_3$. This reaction occurs at low temperature, about 100° C.,[2] the salt subliming in part. There is absorption of heat: $-41{,}300$ calories for the solid and $-37{,}000$ calories for the molten state.

2. Between 180° and 200° C. the decomposition takes place more rapidly, mainly as indicated by the formula: $NH_4NO_3 = N_2O + 2H_2O$. In the decomposition, nitrous oxide (laughing gas) and water are formed, 10,200 calories being liberated for the solid and 14,000 calories for the molten state. At constant volume the temperature and pressure attained are about 555° C. and 4,500 kilograms per centimeter^2, respectively. With fairly good regulation of temperature, 98 percent of the decomposition products follow this reaction. Increasing the temperature causes an increase in production of other nitrogen oxides. Near 260° C. ammonium nitrate burns with puffs of flame. If dissociation of the salt at lower temperatures has given nitric acid and ammonia, these may react to develop a higher temperature as follows: $HNO_3(gas) + NH_3(gas) = N_2O + 2H_2O + 51{,}500$ calories.

3. Explosive reactions of ammonium nitrate develop when the salt is heated rapidly, but explosion occurs only from a very strong initial impulse in an enclosed space or restricted volume. One reaction produces nitrogen, oxygen, and steam as follows: $2NH_4NO_3 = 2N_2 + O_2 + 4H_2O(gas) + 30{,}700$ calories from solid and $+35{,}000$ calories from molten salt, with a possible temperature of 1,500° C. and pressure of 11,200 kilograms per centimeter^2 at constant volume.

4. The reaction may produce nitric oxide, nitrogen, and water according to the formula: $2NH_4NO_3 = N_2O_2 + N_2 + 4H_2O + 9{,}200$ calories for the solid and $+13{,}000$ calories for the molten salt; 518° C. and 4,860 kilograms per centimeter^2, respectively, are the temperature and pressure obtained.

---

[2] The following formulas are given for conversion of metric to English units: Temperature °F. $= 9/5$ temperature °C. $+32$; B. t. u. $= 252$ gram-calories; kg. per cm.$^2 = 14.22$ lb. per sq. in.

5. The reaction may give nitrogen peroxide, nitrogen, and water as follows: $4NH_4NO_3 = N_2O_4 + 3N_2 + 8H_2O(gas) + 29{,}500$ calories for the solid and $+33{,}500$ calories for the molten salt.

6. The reaction may give nitrogen trioxide, nitrogen, and water represented by the formula: $3NH_4NO_3 = N_2O_3 + 2N_2 + 6H_2O(gas) + 23{,}300$ calories for the solid and $+27{,}000$ for the molten salt. This reaction never takes place alone, however, as N_2O_3 exists in the dissociated state only as nitric oxide and nitrogen peroxide.

7. Finally, under certain conditions, such as the presence of spongy platinum and gaseous nitric acid, nitrogen and steam will be obtained following the formula: $5NH_4NO_3 = 2HNO_3 + 4N_2 + 9H_2O(gas) + 33{,}400$ calories for the solid and $+37{,}500$ calories for the molten salt.

Saunders (*10*), by analysis of the gases collected from explosions of ammonium nitrate, found that NO_2, NO, and N_2 were present in the ratio 2 : 4 : 5, indicating an over-all reaction as follows: $8NH_4NO_3 = 16H_2O + 2NO_2 + 4NO + 5N_2$. Under the conditions of the experiment he noted that the explosion was accompanied by a yellow flame similar to that produced by burning ammonia in oxygen.

EXPLOSION HAZARD

Ammonium nitrate is explosible by subjection to a very strong initial impulse, as the detonation of TNT or tetryl. It is also explosible by the application of heat, but this is difficult to accomplish in other than an enclosed space, such as a bomb that retains heat and pressure. There are at least six physical factors that in general influence sensitivity toward explosion: (1) Temperature, (2) strength of initial impulse, (3) density, (4) packing, (5) particle size, and (6) moisture content of the material. Moreover, the acid condition increases sensitivity, as does the presence of such easily oxidizable material as aluminum powder or organic materials. On the other hand, the presence of an alkali or alkaline earth is reported as tending to desensitize ammonium nitrate.

Under conditions of high temperature, great initial impulse, such as a large detonating charge, and high density of material, the explosibility of ammonium nitrate is increased, while increases in particle size and moisture content tend to reduce its sensitivity toward explosion from shock or heat.

Effects of Heating

While the reactions according to the equations given are possible courses for decomposition, they practically never occur singly; but, depending on conditions, one will be the predominant reaction and one or more of the others subordinate. Predominance depends on the rapidity with which a given temperature is reached. Most compounds show a definite mode of decomposition at a definite temperature, and in a given time at that temperature a definite weight of substance is decomposed. Special attention is directed to the peculiar property possessed by ammonium nitrate of decomposing in several ways, according to the rapidity with which a certain temperature is reached and to other factors operating at the time. Experiments made by Kast (*5*) on the effect of heating the material by different methods are summarized in table 1.

TABLE 1.—*Effects of heating ammonium nitrate*[1] *under various conditions*

When in contact with black-powder fuse at—		When dropped on red-hot iron plate		Over a free flame in—		When in a thin iron box[2] placed in a vigorous wood fire
150° C.	200° C.	Intermittent flashes	Burning time	Glass beaker	Melting-point tube	
			Seconds			
No flash; burns quietly with organic matter on a glowing iron plate.	Decomposes; molten; bubbles and fumes; quiet burning.	Flashes immediately; burns off edge of plate; melts; gives off flashes of yellow flame and nitrous oxide fumes.	20 22 25	Melts; deflagrates; decomposes with copious white fumes at end, with puffs of nitrogen oxides.	Vaporizes; no explosion.	Completely vaporized; weak sizzling; no appearance of flash or explosion.

---

[1] Experiments by Kast (*5*); 3 tests for each experiment.
[2] 85-mm. cube filled with 600 gm. of ammonium nitrate.

Sublimation of ammonium nitrate occurs near 100° C., at which temperature considerable decomposition into ammonia and nitric acid has begun; melting occurs at 169°. Between 180° and 200° the decomposition usually gives nitrous oxide and water, as indicated by white fumes. With increased temperature, nitrogen tetroxide (N_2O_4) is produced, and from 230° upward the reaction accelerates rapidly. Under conditions of very rapid heating, with a large mass of salt blanketing in the heat or with constant volume under pressure, explosion may result when the temperature nears 300°. Berthelot (*1*) states that from theoretical considerations the reaction $2NH_4NO_3=2N_2+O_2+4H_2O$ produces a maximum temperature of 1,500° and a pressure of 1,120 kilograms per square centimeter. With reaction 4 (see p. 4) the theoretical temperature is 518° and the pressure 4,860 kilograms per square centimeter; and for reaction 2, temperature is 555° and the pressure 4,500 kilograms per square centimeter.

Under rare conditions of high temperature and pressure it is possible for ammonium nitrate alone to explode. The likelihood of these conditions occurring, however, is remote and can be avoided with reasonable caution.

SENSITIVITY TO LARGE FIRES

Munroe (*7*) cites large conflagrations involving ammonium nitrate and a number of severe test fires of intense heat and high temperatures, without explosion. The burning of the steamer *Hallfried*, with 2,115 tons of ammonium nitrate in its cargo, produced an intense heat but no explosion. A building at Barksdale, Wis., containing 15 tons of ammonium nitrate in barrels, burned completely without explosion; some unconsumed ammonium nitrate was left after the fire. In no case recorded by Munroe had explosion been reported from ammonium nitrate alone stored in a burning building.

DETONATION

Some stimulus is generally necessary for the explosion of a material, but the intensity of the stimulus varies widely, according to the character of the explosive. Low explosives or propellants are combustible and contain oxygen necessary for their own combustion, with the production of sufficient heat to sustain the reaction. In contrast, a high explosive, of which ammonium nitrate is one, will explode under sufficient shock by a primary explosive or detonator. High explosives generally burn quietly in small quantities; they are not readily exploded by heat or shock. Ammonium nitrate under ordinary conditions is inert and can be exploded only through detonation, and then only by using as detonator a quantity of some explosive sufficient to initiate an explosive wave of very high velocity (table 2). This makes the storage of ammonium nitrate under ordinary conditions relatively free from explosion hazard, but caked material should not be broken up by blasting under any circumstances. Table 3 shows the explosibility of ammonium nitrate from different sources, using one detonator in practically the same quantity and varying the quantity of ammonium nitrate.

TABLE 2.—*Sensitivity of ammonium nitrate (German ammonia No. 3) to detonation*[1]

Ammonium nitrate (grams)	Blasting gelatin	Compression of lead block	Result
	Grams	*Inches*	
400	100	⅝	Exploded.
400	75	⅓	Do.
400	50	½	Do.
400	25	0	No explosion.

[1] Reported by Munroe (7).

TABLE 3.—*Explosibility of ammonium nitrate of different amounts and moisture contents*[1]

Sample	Moisture content	Ammonium nitrate	Blasting gelatin	Result
	Percent	*Pounds*	*Grams*	
German	0. 26	15	240	Exploded.
Brunner-Mond	. 84	15	240	Partial explosion.[2]
No. 2 cast	1. 45	40	243	Exploded.
German	. 16	135	243	Exploded; produced crater 12 ft. in diameter and 4 ft. deep.

[1] Reported by Munroe (7); ammonium nitrate exploded by a cartridge of blasting gelatin in contact with the nitrate.

[2] No explanation is given for partial explosion. The difference in explosibility between this and the German material with 0.16 percent moisture may be due to differences in moisture content, or differences in mass may have produced this effect.

PROPAGATION OF EXPLOSION

Following a fire or an explosion in which ammonium nitrate was involved, it has been repeatedly observed that residues of partly consumed or fused salt have been found, showing that ammonium nitrate under such conditions, if exploded, is controlled by limiting factors that prevent the propagation of incendiary or explosive waves. Experiments demonstrating this limitation were performed by Munroe (7) in wooden troughs, 5½ inches square and 10 feet long, resting on the ground. A trough held approximately 125 pounds of ammonium nitrate, which was used both warm and cool; the warm material was placed in the end of the trough where the detonating reaction took place. The warm ammonium nitrate, heated to 52° C., was 99.6 percent pure, with 0.05 percent water; the cool ammonium nitrate, temperature 21°, was 99.19 percent pure, with 0.02 percent water. The effect of detonation was judged from the size and shape of the crater formed.

Experiment 1.—The trough was filled 3 feet with warm ammonium nitrate and 7 feet with cool salt; eight tetryl electric detonators were embedded in the warm salt. The caps alone fired. No explosion occurred.

Experiment 2.—The same as experiment 1, except that one stick of blasting gelatin was used in place of the tetryl as detonator. There was complete detonation of the whole mass. The crater formed was 13 feet long. At the igniting end it was 11 inches deep and 6½ feet wide; at the other end, 7 inches deep and 5 feet wide.

Experiment 3.—The trough was filled with the warm salt and detonated with two sticks of gelatin. The crater was practically the same as in experiment 2.

Experiment 4.—Warm salt only was used. The center 2 feet of the trough contained a layer of salt 1 inch deep and the width of the trough. From this 1-inch depth the salt sloped in the 4 feet to each end, increasing the depth to 5½ inches. One stick of blasting gelatin was detonated in one end. In this end the salt exploded, but the explosion wave failed to pass through the 1-inch strip of ammonium nitrate to the other end. The crater under the exploded end was 8 inches deep, 3½ feet wide, and 4½ feet long. This clearly demonstrated that ammonium nitrate will propagate its own explosion wave, but the force gradually decreases, and in this case was stopped by a 1-inch layer.

Experiments performed by the Consolidated Mining & Smelting Corporation of Canada and reported by the Allied War Supplies Corporation, Montreal, Canada,[3] tested the explosibility of ammonium nitrate in multi-wall paper bags. By detonating dynamite laid on a bag containing ammonium nitrate, the contents of three 80-pound bags of sand that had been piled on top were scattered, but the ammonium nitrate was not more than partially exploded. Intensities of explosion were measured by the sound produced, as indicated by a sound meter, and were essentially the same as that from a blasting charge in sand alone. The results of these tests are shown in table 4. Ammonium nitrate was used in quantities of 25, 50, and 80 pounds. The sound meter was set at zero in tests No. 1 and No. 8. In No. 6 the material was hard-caked: A hole was drilled in it, and the detonating charge placed in the hole and sealed in with more ammonium nitrate. Since no increase in sound over detonating charge with sand alone was evident from the addition of ammonium nitrate, apparently little if any of the ammonium nitrate exploded, although bags were ripped and contents were widely scattered.

TABLE 4.—*Explosibility of ammonium nitrate in paper bags, at Calgary, Canada* [1]

Test No.	Strength of dynamite		Material in which exploded		Sound instrument reading (intensity)	Result
	Percent	Number of sticks	Pound	Kind		
1	40	1	80	Sand	(2)	
2	40	1	80	do	0.4	
3	40	2	80	do	.7	
4	40	1	25	Ammonium nitrate	.7	About 10 to 15 percent exploded; the rest was scattered.
5	40	1	50	do	.75	
6	40	1	80	do	.75	
7	40	2	80	do	.80	
8	60	1	80	Sand	(2)	
9	60	1	80	Ammonium nitrate	1.0	3 sandbags piled on top; bags not completely shredded.
10	60	2	80	do	.75	3 bags of ammonium nitrate on top, covered with sand; partial explosion only.
11	60	2	80	do	.70	Pieces of ammonium nitrate thrown 300 feet; fused appearance.

[1] Reported by the Allied War Supplies Corp.
[2] Zero setting of sound meter.

IMPACT AND FRICTION TESTS

In 10 impact tests made by Munroe (*7*) with ammonium nitrate 99.11 percent pure, containing 0.08 percent water, no explosion was obtained. Ten grams of fine-grained nitrate was used, confined between steel surfaces, on which a 20-kilogram weight was dropped from a distance of 1 meter.

The pendulum friction tests gave no explosion in 190 trials. In this test 10 grams of fine-grained ammonium nitrate was placed on the sliding contact of a steel anvil and a steel pendulum shoe was dropped 2½ meters upon the anvil.

---

[3] Letters to F. W. Parker, in charge, Division of Soil and Fertilizer Investigations, from J. K. Russell, Allied War Supplies Corporation, dated July 31 and October 8, 1943.

Similar experiments by Kast (*5*), shown in table 5, included mixtures of ammonium nitrate with ammonium sulfate. The friction tests gave no explosions with either ammonium nitrate alone or with any of the mixtures. The falling-weight tests showed that with 50 percent or less of ammonium nitrate no explosions were obtained. Kast's tests were performed with dried ammonium nitrate, unless otherwise stated.

TABLE 5.—*Impact tests with mixtures of ammonium nitrate and ammonium sulfate*[1]

[Results from 6 consecutive tests at the same height]

Mixture proportions and action	Falling weight of—										
	10 kilograms from a falling height (centimeters) of—						20 kilograms from a falling height (centimeters) of—				
	6	10	12	16	20	24	6	10	12	14	16
100–0											
No reaction	----	6	6	5	3	3	6	5	4	3	3
Decomposed, no audible report	----	----	----	1	2	1	----	1	1	2	1
Exploded	----	----	----	----	1	2	----	----	1	1	2
75–25											
No reaction	----	----	----	----	----	----	6	5	5	3	1
Decomposed, no audible report	----	----	----	----	----	----	----	1	1	2	2
Exploded	----	----	----	----	----	----	----	----	----	1	3
70–30											
No reaction	----	----	6	6	6	3	----	6	4	3	1
Decomposed, no audible report	----	----	----	----	----	2	----	----	2	2	2
Exploded	----	----	----	----	----	1	----	----	----	1	3
60–40											
No reaction	----	----	----	6	6	5	----	6	6	5	5
Decomposed, no audible report	----	----	----	----	----	1	----	----	----	----	----
Exploded	----	----	----	----	----	----	----	----	----	1	1
50–50											
No reaction	----	----	----	6	6	6	----	6	6	6	5
Decomposed, no audible report	----	----	----	----	----	----	----	----	----	----	1
Exploded	----	----	----	----	----	----	----	----	----	----	----

[1] Data given by Kast (*5*).

EFFECTS OF ADDED INORGANIC SUBSTANCES

Ammonium nitrate is used as an explosive primarily in mixtures with other materials, as TNT, which furnish the initial energy to propel the explosion wave through the ammonium nitrate. The double salt of ammonium sulfate-ammonium nitrate produced in Germany and marketed as Leunasalpeter is prepared by mixing the two ammonium salts in equimolecular proportions (80 pounds ammonium nitrate to 132 pounds ammonium sulfate), approximately 40 to 60. This mixture was considered safe under all storage conditions until the Oppau explosion. Experiments reported by Munroe (*7*) on detonating mixtures of these two salts in different proportions gave the results shown in table 6. Detonation was carried out by placing blasting gelatin and a charge of 400 grams of the mixed salts in a beaker on a lead block 4 inches high and 2¼ inches in diameter.

After an explosion the effect was shown by measuring the impression in the lead.

The results indicated in tables 5 and 6 compared with those for ammonium nitrate alone, as given in table 2 and in table 4, show the relative explosibility under different tests. A 50–50 mixture gave negative results under repeated tests by Kast (*5*) with falling weight and friction, as well as those by Munroe (*7*) of 60–40 using a blasting gelatin detonator.

TABLE 6.—*Explosibility of 400 grams of ammonium-nitrate and ammonium-sulfate mixture, using blasting gelatin detonator* [1]

Mixture proportion	Blasting gelatin	Compression of lead block	Results
	Grams	*Inches*	
90–10	100	¾	Detonation.
90–10	75	¾	Do.
90–10	50	0	No detonation.
80–20	100	¼	Detonation.
80–20	75	½	Detonation.
80–20	50	0	No detonation.
70–30	100	0	Do.
60–40	100	0	Do.

---

[1] Tests by Munroe (7).

Explosive tests were made by the Underwriters' Laboratories, Inc. (*9*) with mixtures of ammonium nitrate-ammonium sulfate (40–60) and with ammonium nitrate-calcium carbonate (60–40). The conclusions were that the products were not explosive under conditions met with in practice. Even in the presence of organic matter at comparatively high temperatures no evidence of a violent or explosive reaction was obtained. These conclusions applied only to those mixtures corresponding to Leunasalpeter and Cal-Nitro.

The reaction for the decomposition of a mixture of ammonium sulfate-ammonium nitrate reaches a temperature of about 1,200° C.—almost equal to that for ammonium nitrate alone. The explosive reaction of the double salt, ammonium nitrate-ammonium sulfate, is believed to take place according to the following composite equation: $2NH_4NO_3+(NH_4)_2SO_4=8H_2O+SO_2+3N_2+150{,}000$ calories.

Tests were made by Kast (*5*) with about 2 kilograms of mixtures of ammonium nitrate and other salts in an iron pipe 10 centimeters in diameter and 37 centimeters long, with a charge of 100 grams of picric acid as detonator. Incomplete explosions occurred for ammonium nitrate mixed with ammonium carbonate in the weight ratio 50–50, with ammonium chloride 55–45; with potassium chloride 80–20; and with water-free calcium sulfate 90–10. There was no explosion of mixed potassium nitrate and ammonium chloride, 90–10, or for the double salt $NH_4Cl.KNO_3$. Details of these experiments are given in table 7. Tests are reported with a mixture containing 33.4 percent ammonium nitrate-ammonium sulfate, 53.6 percent superphosphate, and 13 percent sand. Using the lead block, impact, and friction tests for detonation gave no indication of the mixture exploding.

TABLE 7.—*Explosion tests with ammonium nitrate and other salts* [1]

Salts (2 kilograms)	Mixture proportion	Weight of charge [2]	Density	Effect on iron container [3]	Action on supporting lead plate	Effect on salt	Result
		Grams					
Ammonium nitrate-ammonium carbonate.	60–40	2, 230	0. 8	In jagged strips	Indented 3.3 cm. deep, 17 cm. wide.	Decomposed	Explosion.
Do	50–50	2, 230	. 8	Strips 5 to 10 cm. wide	No effect	Partly decomposed	Incomplete explosion.
Ammonium nitrate-ammonium chloride.	70–30	2, 350	. 8	Strips 5 to 8 cm. wide	Indented 3.3 cm. deep, 17 cm. wide.	Decomposed	Explosion.
Do	60–40	2, 250	. 8	Jagged strips upper part; smooth edges lower part.	Indented 2.5 cm. deep, 15 cm. wide.	do	Do.
Do	55–45	2, 240	. 8	Upper part torn, lower split smoothly to near end.	No effect	Partly decomposed	Incomplete explosion.
Ammonium nitrate-potassium chloride.	90–10	2, 360	. 8	Split in smooth strips	Indented 2.5 cm	Decomposed	Explosion.
Do	80–20	2, 480	. 85	Smooth strips, 3 cm. wide; upper part jagged.	No effect	Partly decomposed	Incomplete explosion.
Ammonium nitrate-calcium sulfate.	94–6	2, 650	1. 0	Strips 5 to 8 cm. wide	Indented	Decomposed	Explosion.
Do	90–10	2, 600	1. 0	Smooth strips, 3 cm. wide; upper part very jagged.	No effect	Partly decomposed	Incomplete explosion.
Potassium nitrate-ammonium chloride.	90–10	3, 220	1. 2	Upper half torn apart; lower not ruptured.	do	Mostly unchanged	No explosion.
Double salt ($NH_4Cl.KNO_3$)		3, 030	1. 0	do	do	Compressed in container	Do.

[1] Experiments by Kast (*5*).
[2] Priming charge in all cases consisted of 100 additional gm. of picric acid.
[3] Iron pipe, 10 cm. in diameter and 37 cm. long.

ADDITION OF ORGANIC MATERIALS AND OXIDIZABLE POWDERS

Heating ammonium nitrate alone and with impurities to determine the flash point showed that ammonium nitrate alone decomposed completely between 245° and 340° C. without flame but with red fumes, 5 percent paraffin gave decomposition without flame at 270° C., and 30 percent paraffin gave a flame one time in three tests at 300° C.; in other cases decomposition occurred without flame. Mixed with ammonium nitrate and heated to 240° to 250° C., 5 percent aluminum, iron, and zinc powders each gave decomposition and deflagration without sustained flame. These experiments indicate a reduction of explosion hazard by the presence of small quantities of paraffin, but oxidizable metal powders increase the explosion hazard by lowering decomposition temperatures.

Considerable interest attaches to the use of waxy materials for coating as a possible source of danger, increasing the sensitivity of ammonium nitrate as an explosive or a fire hazard. As shown in table 8, ammonium nitrate with 5 percent paraffin decomposes at a considerably higher temperature than without any addition. This is in line with a report by Bezold (*2*) that paraffin is employed for decreasing moisture absorption, but it also decreases explosibility. Coating ammonium nitrate with about 1 percent of petrolatum-rosin-paraffin mixture does not appreciably increase explosibility.

TABLE 8.—*Flash point of ammonium nitrate mixed with organic and metallic powders* [1]

[Average of 3 tests heated slowly to 360° C.]

Ammonium nitrate (grams)	Substance added		Effect of heating in Woods-metal bath
	Kind	Percent	
3.0	None		At 180°, melts; at 220°, light gray fumes; at 245°–340°, decomposed, sputtering, red-brown fumes.
3.0	Paraffin	5	At 270°, decomposed without flame.
	do	30	At 290°, decomposed; at 300°, small flame once.
3.0	Naphthalene	30	At 270°–295°, decomposed.
3.0	Iron oxide	5	At 290°, gray fumes, decomposed without flame.
	do	5	At 210°, light gray fumes; at 245°–255°, decomposed with sputtering, no flame.
0.5	Beech charcoal	5	At 200°–210°, gray fumes, bubbling, decomposed, without flame.
0.5	Charcoal not fully charred	5	Above 180°, white fumes; above 220°, sputtering, decomposed without flame.
	do	11	At 160°, white fumes; 205°–208°, very small flame, puffs of gas, decomposed.
	do	5	At 200°, grayish fumes; at 205°–211°, bubbling, decomposed, no flame.
0.5	Wood powder	5	Above 180°, fumes; above 220°, bubbling, decomposed, no flame.
	do	5	At 200°, gray fumes; at 205°–212°, puffs of gas, decomposed, no flame.
0.5	Aluminum powder	5	From 180°, gray fumes; above 240°, bubbling and decomposed.
0.5	Iron powder	1	At 250°, decomposed, puffs of gas.
	do	5	Do.
0.5	Zinc powder	1	Do.
	do	5	Do.
	do	20	Do.

[1] Experiments by Kast (*5*).

It is reported by Marchand (*6*) that molten ammonium nitrate does not react with aluminum, iron, mercury, or tin, but it does react with bismuth, cadmium, copper, magnesium, lead, nickel, and zinc. Cadmium and copper are most reactive. These metals form nitrates and set free hydrogen, which reduces some nitrate to ammonium nitrite. This much less stable compound increases the explosion hazard. Care should therefore be taken to keep these metals away from stored ammonium nitrate. Inasmuch as cadmium is present in zinc, which is used in all galvanizing work, the use of galvanized vessels or storage in contact with the galvanized siding of buildings should be avoided.

FIRE HAZARD

Special attention has been given to the fire hazards presented in the storage and handling of ammonium nitrate and its mixtures prepared for fertilizer use. Munroe (*7*) and the Underwriters' Laboratories (*9*) made many tests, in order to establish as nearly as possible the hazards from ammonium nitrate alone, its mixture with ammonium sulfate as represented by Leunasalpeter, and with ground limestone as in Cal-Nitro. The conclusion arrived at by each was that ammonium nitrate, like nitrates in general, presents a fire hazard of the same order as from sodium nitrate.

Cadmium readily dissolves in cold aqueous solution of ammonium nitrate and reacts to form cadmium nitrate and later cadmium nitrite. Reactions due to decomposition of ammonium nitrate are referred to later under the heading Spontaneous Combustion Due to Ammonium Nitrate (p. 16). Zinc, magnesium, nickel, copper, and lead react slowly; iron, aluminum, silver, and mercury slightly. In most cases nitrate is formed. Boettger (*3*) states that if ammonium nitrate is dissolved in water and an amount of zinc dust equal to the ammonium nitrate is thrown into the liquid, the temperature suddenly rises, the liquid boils violently, finally explodes, and if a beaker is used for the experiment the vessel is shattered. This has been verified on a number of occasions.

Combustion of Ammonium Nitrate Alone

All nitrates furnish oxygen to support combustion, and explosive nitrates will burn under some conditions if they contain oxidizable elements, and will partially support their own combustion, which may result in an explosion. Ammonium nitrate is in this class, but, as already shown, this requires confinement, a high temperature, and a high density of material. These are generally produced only by intentional arrangement, and under most conditions the explosive wave will not follow broken masses. For the same reason, heat is not usually generated in sufficient quantity to support combustion of ammonium nitrate alone. It may be ignited by organic matter associated with it and may burn and furnish sufficient heat, but ignited ammonium nitrate alone will soon cease burning from loss of heat. Since over-all reactions in decomposition are mostly endothermic below 260° C., it requires more heat than is generated by the reactions to continue the decomposition.

In a number of tests by Munroe (*7*), where fires were started from free flames or by detonation, ammonium nitrate contained in wooden barrels was fused, scattered, or partly burned, but the fire did not spread throughout the mass. Often unchanged ammonium nitrate remained with unconsumed parts of barrels. A recent test carried out by the Consolidated Mining & Smelting Corporation of Canada and reported by the Allied War Supplies Corporation, Montreal,[4] showed that 10 pounds of ammonium nitrate, sprinkled with gasoline in a paper bag and ignited, burned quietly and left a mass of partly fused ammonium nitrate with some of the unburned paper bag. A second test was made with similar material, except that enough gasoline was added to make a slurry with the salt. This was placed on a pile of wood soaked with gasoline and ignited. Burning was brisk but not fierce; molten ammonium nitrate dripped on incandescent coals and burned, but no evidence of explosion was obtained.

Similar tests have been made at the Plant Industry Station of the Agricultural Research Administration, at Beltsville, Md., using 10 pounds of ammonium nitrate with essentially the same results. In one test, after the pile of wood had been reduced almost to a bed of coals, additional fuel was piled on and another 5 pounds of ammonium nitrate added. The fire burned rapidly and the ammonium nitrate melted, flowed over the hot coals, and burned, giving off reddish-brown fumes. The ammonium nitrate was completely decomposed, but there was no evidence of explosion. Evidence by other experimenters, showing the presence of undecomposed ammonium nitrate remaining after explosions or fires had started from organic combustibles, indicates that while the salt may add to the intensity of a fire after it has reached a high temperature it does not of itself propagate flame readily.

Influence of Added Materials

Fire tests by A. H. Nucholls, of the Underwriters' Laboratories, Inc. (*9*), were performed with mixtures of ammonium nitrate and ammonium sulfate in the ratio of about 40–60 (base No. 1) and of ammonium nitrate and calcium carbonate in the ratio of about 60–40 (base No. 2), mainly to determine the violence of the reaction that occurs under fire conditions when these products are in contact with sawdust or other organic matter. Tests were made also with burlap bags used previously for storage of the ammonium nitrate-ammonium sulfate mixture and bags used for sodium nitrate.

Tests were made with 40-pound samples of nitrate-sulfate and nitrate-carbonate mixtures alone and with slightly smaller samples mixed with sawdust. Each sample was placed in a cylindrical brick furnace, 11 inches inside diameter and 15 inches high, surrounded by a metal cylindrical shield, 22 inches in diameter and 35 inches high.

Three 6-inch equidistant circular openings in the side of the brick furnace near the bottom were temporarily covered by ¼-inch boards when the test sample was placed in the furnace. The sides of the metal shield carried corresponding openings through which flames 4 feet long and 1 foot in diameter were directed from kerosene blowtorches operated by compressed air. A thermocouple inserted in the ammonium-nitrate mixture indicated temperatures during initial stages of a test. The three torches were started at the same time, and the wood covers on the openings in the brick furnace burned, permitting the flames to impinge directly on the material under test. Three tests were made with base No. 1 alone and one test with 30 pounds of base No. 1 mixed with 7 pounds of sawdust. Two tests were made with base No. 2 alone and one with No. 2 mixed with 2¼ pounds of sawdust.

---

[4] See footnote 3, p. 9.

With ammonium nitrate-ammonium sulfate (No. 1) and sawdust mixed in, the samples melted and decomposed to some extent. Odors of ammonia, sulfur dioxide, and some sulfur trioxide were recognized. The maximum temperature observed was 668° C. A black carbonaceous residue remained with the sawdust. Similar observations were made with base No. 2, except that the highest temperature was 979°. In no case were brown fumes observed, and the samples did not react violently or explode. Sawdust did not seem to increase the violence of the reaction, but left a charred residue. The absence of brown fumes and the presence of charred residue indicate a deficiency of oxygen under the conditions of these tests. With free access of air, as might occur in accidental fires, the reactions would probably be somewhat more violent.

Spontaneous Combustion Due to Ammonium Nitrate

There has been some apprehension that even the small quantity of organic material contained, as 0.5-percent coating of petrolatum-rosin-paraffin, might slowly oxidize and thereby constitute a hazard of spontaneous combustion, possibly followed by explosion. With this possibility in mind, T. H. Wilde, Assistant Director of Inspection (Explosives), Canada,[5] carried out tests with coated ammonium nitrate tightly packed into thermos bottles; he observed the temperature of the center of the material while the bottles were stored in a room at approximately 60° C. for 2 weeks. There was not the slightest change in temperature with dry samples or with those to which 0.5 percent and 1 percent moisture had been added. Wilde concluded that there is no evidence to support the theory of oxidation of the organic-coating material with resultant heating and that the addition of 0.5-percent PRP wax should have no adverse effect on the material as regards likelihood of spontaneous ignition. Flash temperatures with coated material were essentially the same as those previously determined for untreated material, indicating no increased hazard from adding the coating.

Tests were performed at the Soil and Fertilizer laboratory, Plant Industry Station, using large thermos bottles containing untreated ammonium nitrate and samples treated with wax and rosin coating. Samples were kept in a constant-temperature room maintained at 45° C.±2° (114° F.) for 6 weeks, with ±0.002° C. fluctuation in the thermometers buried in 5- to 8-pound samples of ammonium nitrate. There was no indication of spontaneous heating in the samples with wax or rosin coating or in the untreated materials.

It has been found in this laboratory that certain mixtures of ammonium nitrate, organic materials, and superphosphate are subject to spontaneous combustion. A mixture composed of 1,400 pounds of ordinary superphosphate, 400 pounds of ammonium nitrate, and 200 pounds of peanut-hull meal ignites spontaneously when the mass is heated in an oven until the temperature nears 90° to 95° C. Decomposition of ammonium nitrate and reaction with superphosphate liberates free nitric acid. A chain of oxidizing and exothermic reactions follows rapidly, raising the heat internally under insulating conditions to the ignition point. About 3 percent ammonia added to the superphosphate will prevent the reactions causing combustion.

---

[5] See footnote 3, p. 9.

Flash Point of Ammonium Nitrate

Among the tests performed by the Consolidated Mining & Smelting Corporation and reported by the Allied War Supplies Corporation[6] was a series determining the flash points of untreated and treated ammonium nitrate, the latter as prills and crystalline material coated with oil, wax, paraffin, or kieselguhr. Twenty grams of material were dropped on a thin steel plate floating on molten lead or tin. The flash point was taken as the temperature at which 50 percent of the trials of a sample ignited on contact with the plate. Some samples formed a ball that danced over the surface of the plate and flashed at a temperature higher than the usual flash point. Again, if a sample slipped to the edge of the plate and came in contact with the steel plate and molten metal, it flashed immediately at a temperature below that of the flash point on the plate surface. With the quantities of materials employed there was no appreciable difference between the treated and untreated ammonium nitrate. The flash point in one series in which a tin bath was used varied from 464° to 478° C.; in another series with lead bath, from 510° to 580°. The same materials were used in each series, but an iron-constantan thermocouple was used in the first series and chromel-alumel in the second. There is some indication from the flash tests that wax and paraffin coatings raise the flash point slightly. The effects of slow and rapid heating of ammonium nitrate plus minor quantities of other materials are shown in tables 8 and 9.

Table 9.—*Results of heating ammonium nitrate (3 grams) mixed with charcoal and metallic substances*[1]

[Three tests each, heated rapidly]

Substance added		Effect of heating in direct contact with burning fuse
Kind	Percent	
Beech charcoal	5	Not ignited.
Partly charred wood	5	Do.
	11	Ignited in 2 tests; 1 failed.
Wood meal	5	Not ignited.
Aluminum powder	5	Do.
	28	Do.
Zinc powder	5	Do.
	20	Decomposed without flame.
Iron oxide	5	Not ignited.

[1] Experiments by Kast (*5*).

Bags and Other Containers

Of particular interest are the fire tests made by the Underwriters' Laboratories (*9*) on bags used for storage of sulfate-nitrate mixture over periods of 3 to 10 months. The fabric contained about 1 ounce of absorbed salts per square foot, or 0.197 gram per square inch. Comparative tests were also made, using similar bags washed thoroughly and with bags containing 1 ounce of sodium nitrate per square foot. Test strips from the bags, 4 inches wide and 6½ feet long, were suspended by one end in a long sheet-iron box 12 inches square with mica windows. A gas flame 11 inches high was located 4 inches below a hanging bag strip. The periods of time necessary for ignition of the material, for combustion, and for afterglow of the specimens to remain visible were observed. The average ignition periods of the washed, the sodium nitrate, and the ammonium sulfate-ammonium nitrate strips were 4.33, 2.32, and 6.58 seconds, respectively; the average combustion periods in the same order were 86, 31, and 59 seconds; and the afterglow was 163, 360, and 560 seconds.

---

[6] See footnote 3, p. 9..

Tests at the Plant Industry Station laboratory were made with strips from burlap bags and from laminated (asphalt layer) paper bags, soaked in solutions of ammonium nitrate, sodium nitrate, and mixtures of salts, and compared as to burning properties after oven drying. When both salts were well dried, strips from bags soaked in sodium nitrate burned with more violence than those soaked in ammonium nitrate. The sodium-nitrate bag strips sputtered and dripped molten salt, and in these respects was in contrast to the quiet burning of the strips soaked in ammonium nitrate.

Tables 10 and 11 show the results of two series of tests with each type of bag. The strips were soaked in solutions of the salts and dried at 105° C. for series 1 and at 75° for series 2. The strips in series 1 contained less salt than those in series 2. With both types of bags the series 1 strips burned more readily and with less afterglow than those in series 2. While the time of burning for ammonium nitrate and sodium nitrate was essentially the same, the strips of both kinds containing sodium nitrate burned with sputtering and dripping of molten salt, in contrast to the quiet burning of ammonium-nitrate strips. In one case, ammonium-nitrate strips dried overnight at 105° were in ashes in the oven next morning. Later drying was done at 75°; a shorter heating period gave partly charred fabric at 100°. Partial decomposition of ammonium nitrate at 100° may have left a nitric-acid residue, increasing oxidation and therefore producing combustion. The more vigorous burning of series 1 strips as compared to series 2 may be due to better drying at 105° than at 75°. There is also some indication that a high percentage of salt impregnation reduces the vigor of burning but prolongs smoldering.

According to the National Fire Protection Association (*8*), "Oxidizing material, bags, or barrels may become impregnated with nitrate, in which condition they are readily ignitible. In contact with organic or other readily oxidizable substances it [nitrate] will cause violent combustion on ignition."

TABLE 10.—*Combustion of impregnated 5-ply paper-bag strips*[1]

Series and test No.	Size	Weight	Salt used[2]		Period of burning	Period of afterglow	Burning conditions
			Kind	Concentration			
	Inches	*Grams*		*Percent*	*Seconds*	*Seconds*	
Series 1 (dried at 105° C.):							
1	2.5×7	6.32	None		31		Quiet.
2	2.5×7	7.75	do		33		Do.
3	2.5×7	6.22	Ammonium nitrate	0.5	24		Quiet, rapid.
4	2.5×7	6.45	do	18.0	24		Do.
5	2.5×7	6.65	Sodium nitrate	13.0	20		Rapid, sputtering.
Series 2 (dried at 75° C.):							
1	3×13	9.6	None		50	30	Quiet.
2	3×13	9.6	do		48	8	Do.
3	3×13	9.4	Ammonium nitrate	31	32	3	Quiet, rapid.
4	3×13	10.0	do	32	26		Do.
5	3×13	9.5	Sodium nitrate	30	25	30	Rapid, sputtering.
6	3×13	9.2	do	32	20	42	Do.
7	3×13	10.5	Ammonium nitrate and sodium nitrate	30	64		Slow and irregular, some sputtering; small flame.
8	3×13	9.6	do	32	48		Do.
9	3×13	10.4	Ammonium sulfate	23			None.
10	3×13	9.6	do	26			Do.
11	3×13	9.6	Ammonium nitrate and ammonium sulfate.	34			Do.
12	3×13	9.9	do	34			Do.

[1] Experiments made by J. Y. Yee, Soil and Fertilizer Investigations.

[2] Strips were dipped in salt solution and dried; lower end of suspended strip was ignited by gas flame.

TABLE 11.—*Combustion of impregnated burlap strips* [1]

Series and test No.	Size	Weight	Salt used [2]		Period of burning	Period of afterglow	Burning conditions
			Kind	Concentration			
Series 1 (dried at 105° C.):	*Inches*	*Grams*		*Percent*	*Seconds*	*Seconds*	
1	2.5×7	4.7	None		39	74	Fairly even; ash breaks off in glowing pieces.
2	2.5×7	4.8	do		36	72	Do.
3	2.5×7	4.8	Ammonium nitrate	31	20	60	Quietly and rapidly; unevenly on one side.
4	2.5×7	4.9	do	35	23	47	Quietly and rapidly.
5	2.5×7	4.9	Sodium nitrate	35	15	25	Rapidly, unevenly; molten salt dripped off, reignited on table top.
6	2.5×7	5.2	do	34	22	56	Do.
Series 2 (dried at 75° C.):							
1	3×13	7.2	None		34	84	Uneven, quiet.
2	3×13	7.2	do		38	49	Do.
3	3×13	7.2	Ammonium nitrate	43	23	119	Quiet, rapid; ash hangs together.
4	3×13	7.4	do	43	18	102	Do.
5	3×13	7.5	Sodium nitrate	41	79	35	Irregular, sputtering, drops of molten salt; ash breaking made timing difficult.
6	3×13	7.5	do	42	22		Do.
7	3×13	7.6	Ammonium nitrate and sodium nitrate	41	54	34	Similar to above; less sputtering; small red flame.
8	3×13	7.4	do	40	35		Do.
9	3×13	7.1	Ammonium sulfate	29			None.
10	3×13	7.6	do	26			Do.
11	3×13	7.8	Ammonium nitrate and ammonium sulfate.	40			Do.
12	3×13	7.9	do	41			Do.

[1] Experiments made by J. Y. Yee, Soil and Fertilizer Investigations.

[2] Strips were dipped in solution of salt and dried; lower end of suspended strip was ignited by gas flame; strips drying at 105° C. overnight were reduced to ashes next morning, apparently by spontaneous combustion; subsequent drying at 105° was limited to 4 hours; slight browning was observed.

The results of the various tests indicate that paper or burlap bags impregnated with ammonium nitrate and mixtures of ammonium nitrate with other nitrogen carriers or sodium nitrate and dried, burn more vigorously than these materials without treatment, but the presence of ammonium nitrate makes the fabric no more combustible under most conditions than does sodium nitrate.

Kast (*5*) concluded that wood and paper impregnated with ammonium nitrate is more difficult to ignite than the untreated material. When once ignited, however, the intensity of a fire is greater with such mixture under conditions in which there is free access of air. Fabric impregnated with ammonium nitrate heated to approximately 100° C. appears to offer a fire hazard, and, as indicated in a previous section, prolonged heating at somewhat lower temperatures with easily oxidizable material may result in spontaneous combustion under some conditions.

Secondary Hazard of Ammonium-Nitrate Fire

A hazard associated with fires involving the presence of ammonium nitrate is the generation of dangerous fumes from decomposition of the nitrate at temperatures usually found in large fires. Large quantities of brown fumes, oxides of nitrogen, are given off. These are irritating to the throat and lungs and very dangerous if inhaled for an appreciable time. Often the effects from inhaling considerable quantities of these oxides do not appear severe for several hours afterward, when edema and even death may result. Special care should be taken not to inhale fumes from fires involving ammonium nitrate.

SAFETY MEASURES

Ammonium nitrate, untreated or treated, should be stored in a dry location, preferably fireproof, but, in any event, away from combustible material.

Laminated, waterproofed paper or fabric bags may be used for packaging these materials, and filled bags should be stacked to allow ample ventilation.

Combustible materials or easily oxidized metals, especially copper if finely divided, should be stored at a distance, in order to prevent accidental mixing with ammonium nitrate.

Mixtures containing acid salts or free acid, ammonium nitrate, and organic material should not be stored unless neutralized with ammonia.

Ammonium nitrate may be stored in bulk, only in a form definitely known not to cake in the time it will be stored. Bulk storage often results in severe caking, which makes it difficult to handle without blasting

Caked ammonium nitrate should never be broken up by blasting with explosives.

Commercial fertilizer mixtures containing ammonium nitrate require no special precautions regarding explosions and may be handled in the same way as similar mixtures containing sodium nitrate. It requires the presence of more than 50 percent of ammonium nitrate with ammonium sulfate to make the mixture explosible under violent shock-test conditions.

Bags that have contained ammonium nitrate should not be piled even temporarily in or near a wooden building, as they are inflammable. Bags should be burned promptly after emptying.

Bearing in mind that ammonium nitrate is explosive and supports combustion, it should be handled in such a way as to avoid conditions that would make it dangerous. More than ordinary caution should be practiced along the lines indicated, but no violent reactions need be anticipated from impacts, jars, or friction, which must be avoided with more sensitive explosives.

Should ammonium nitrate be involved in a burning building or in a fire with other combustible material, ordinary fire-fighting methods should be used to extinguish it. Water is generally the most convenient and effective; it will exert its usual cooling effect in extinguishing a fire.

Fumes from burning ammonium nitrate are extremely toxic and should not be inhaled. Persons who fight fires in which these chemicals are concerned should wear gas masks.

Mixtures containing superphosphate, organic conditioner, and ammonium nitrate may ignite spontaneously in storage if the temperature reaches 90° C. (194° F.); neutralization by ammonia eliminates this possibility.

LITERATURE CITED

(1) Berthelot, M.
1883. sur la force des matières explosives. Ed. 3, 2 v., illus. Paris. [Trans. and condensed by C. N. Hake and W. Macnab. 563 pp., illus. London. 1892.]

(2) Bezold, H. von.
1932. die verwendung des paraffins in der sprengstoffindustrie. Nitrocellulose 3: 119–121.

(3) Boettger, R.
1878. erzeugung eines tiefen, wie eines hohen temperaturgrades durch ammonium-nitrat. Chem. Centbl. 9: 560.

(4) Kast, H.
1925. die explosion in oppau am 21, september 1921, und die tätigkeit der chemisch-technischen reichsanstalt. Ztschr. f. das Gesam. Schiess u. Sprengstoffw. 20: 1–12, 17–43, illus.

(5) ———
1926–27. ueber explosible ammonsalze. Ztschr. f. das Gesam. Schiess u. Sprengstoffw. 21: 204–209, illus; 22: 6–9, 30–34, 56–61, 77–80, 99–102, 131–135, 208–213, 243–247, 279–283, illus.

(6) Marchand, R. F.
1838. die untersuchung des schiesspulver. Jour. f. Prakt. Chem. 13: 505.

(7) Munroe, C. E.
1922. the explosibility of ammonium nitrate. Chem. & Metall. Engin. 26: 535–542, illus.

(8) National Fire Protection Association.
1944. table of common hazardous chemicals. Ed. 7. 31 pp. Boston.

(9) Nuckolls, A. H.
1940. fire and explosion hazards of ammonium nitrate fertilizer bases. Underwriters' Lab. Res. Bul. 20, 31 pp., illus. [Sponsored by Natl. Board of Fire Underwriters.]

(10) Saunders, H. L.
1922. the decomposition of ammonium nitrate by heat. [London] Chem. Soc. Jour. 121(1): 698–711, illus.

U. S GOVERNMENT PRINTING OFFICE: 1945

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents

LIBRARY
CURRENT SERIAL RECORD
☆ APR 14 1945 ☆
U. S. DEPARTMENT OF AGRICULTURE